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A Survey on Opportunistic Routing Protocols for Wireless Sensor Networks

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Abstract

Opportunistic routing is a new paradigm in routing for wireless sensor network which chooses the node closest to the target node for forwarding the data. It uses the broadcasting nature of wireless sensor networks. Opportunistic routing has increased the efficiency, throughput and reliability of sensor networks. Many energy saving techniques has been introduced using opportunistic routing in wireless sensor networks for increasing the network lifetime. In this article we have elaborated the basic concept of Opportunistic routing, different areas in which it has been claimed to be beneficial, some protocols their metrics and their drawbacks.

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Keywords: Wireless Sensor Networks (WSN); Opportunistic Routing (OR)

1. Introduction

Wireless sensor networks (WSNs) are the network of spatially distributed sensors which gathers information from the physical world. It is used for monitoring environmental factors like temperature, pressure moisture etc. and send this data to the sink or destination node. WSN has proven beneficial in number of applications in the area of traffic surveillance, military application, weather forecasting, landslide detection, fire detection etc. It is the backbone of the emerging technologies like Internet of Things (IoT), cyber physical system (CPS) etc. The most interesting contribution of WSN is in the healthcare. WSN in healthcare itself is the topic of

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research which has gained much popularity these days. The potential of sensing the information from the physical entities makes the wireless sensor network a hot topic for the research.

Routing is the difficult task in terms of wireless sensor network. Designing a routing protocol for wireless sensor network is different from designing it for the traditional networks. In case of the WSN, there is a strict energy saving requirement and there is a issue of the increasing network lifetime. Therefore, while designing the routing protocol for WSN resource management is important. The main function of the routing is route selection and data forwarding. The route selection includes selecting the best route between two nodes. The data transmission is done by selecting the next node or hop to forward the data. The packet forwarding in the traditional routing approaches for multihop wireless networks is done by selecting the node proactively at the sender side before transmission. Traditional multi-hop routing strategies suppresses the broadcasting nature of the wireless networks by using the Automatic Repeat Request [ARQ] or Forward Error Control [FEC] Data link techniques[8].

The new approach discussed in this article uses the broadcasting nature of the wireless network for packet forwarding. This approach is named as "Opportunistic Routing (OR)". The key idea behind OR is to use the broadcasting nature of wireless network such that transmission from one node can be overheard by multiple nodes. Instead of choosing the next forwarder node ahead of time, the OR chooses the next node dynamically at the time of transmission. The forwarding is done by the node closest to the destination. It has been shown that OR gives better performance than traditional routing. The key task of the OR is to select the forwarder set and prioritize the nodes in the set. Consider the following example. Here the source node S has four intermediate nodes with packet delivery probability of 15%. Each intermediate node has packet delivery probability of 85% to the destination. Traditional routing will choose only one intermediate node for data forwarding, while OR will consider all these nodes for data forwarding. Thus, OR proves to be more efficient and reliable than traditional routing. In the remaining paper the existing work related to the OR in different types of networks and its comparative analysis [14, 15, 16].

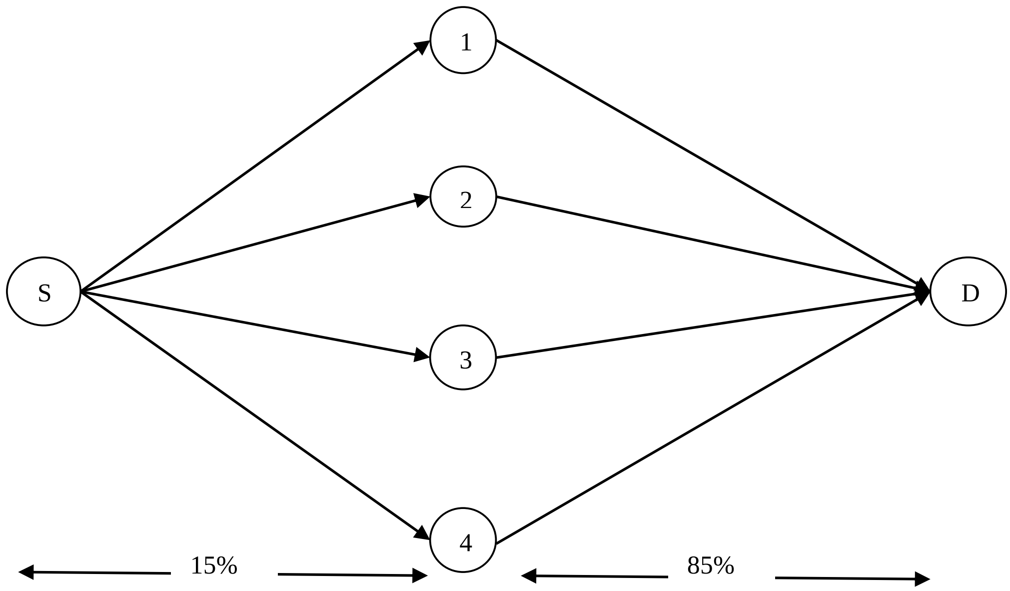

Fig. 1. Illustration in which each source node has multiple intermediate nodes along with packet delivery probability for data transmission to the destination node.

2. Literature Survey

A brief survey on different opportunistic routing protocols

2.1 Geographic Random Forwarding (GeRaF) for Ad Hoc and Sensor Networks: Multihop Performance[1]

In this paper**,** the author proposes the scheme called Geographic Random Forwarding, which is based on geographic routing. In wireless network the relay node is not known by the sender but is decided after the transmission. It uses the telecasting nature of the wireless network. Since the topologies are randomly changed, the sender node does not know which of its neighbouring node will act as a relay node. Hence, to deal with contention at the receiver end, author has proposed the above scheme. The basic idea of the paper is as follows: The sender node simply broadcasts the packet along with its own location and destination location. All the listening node in the neighbour will receive the packet and based on the own distance from the destination, they prioritize themselves to act as relay node. The relayed packet is then sent to a broadcasting address which also contains the transmitter and final destination location thus providing a geographic route without maintaining routing table.

Thus this paper describes the forwarding approach based on the geographic location and the random selection of the relay node through the contention at the receiver side. The analysis of the multihop performance is done in terms of the number of hops to reach to the destination as a function of distance and the number of nodes in the neighbour nodes.

2.1 ExOR: Opportunistic Multi-Hop Routing for Wireless Networks[2]

This is the first most basic protocol which practically implemented the Opportunistic Routing in the wireless networks. ExOR uses batches to send the packets. The source node collects the packets which are intended to the same destination and groups them into a batch. Each batch has its own Batch ID. The source node chooses the Batch ID and the forwarder list prioritized based on the ETX metrics[3]: shorter the distance of node from target node higher the priority. Only the nodes having higher priority are included in the forwarder list. Each node in the forwarder list maintains a local batch map. The node adds the packet into the packet buffer for the corresponding batch. The node compares the entry for each batch map in the packet with corresponding entry in the local batch map and if the higher priority entry is detected, it replaces the entry in the local batch map. ExOR implements scheduled transmission of packets to ensure that only one node sends the packet at one time.
The following example illustrates the working of ExOR.

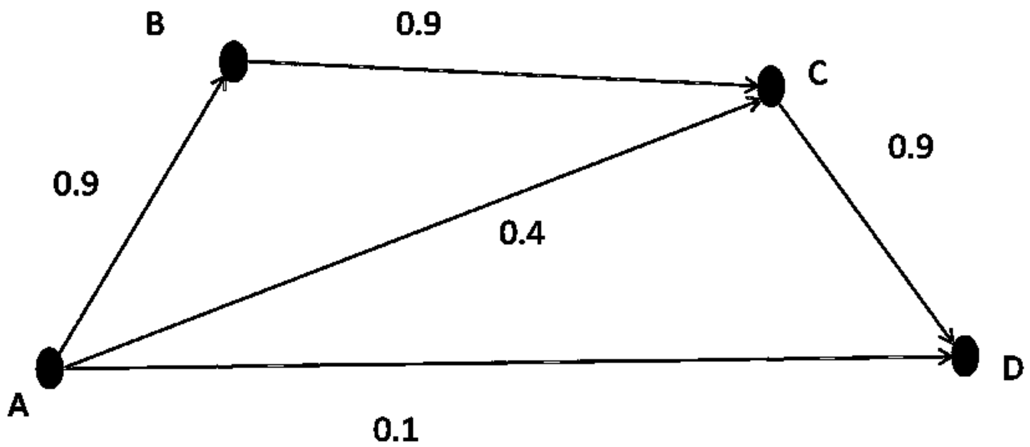

Fig. 2. Example of four node network with link delivery probabilities.

In the above network, there are four nodes connected to each other along with their link delivery probabilities.

Suppose Node A wants to send the packet to node D, so for A, the list of forwarding nodes will be (D,C,B) Because EXOR tries to send the packet to the node which has least remaining distance from the destination. So if B, C, D receive the packet then each of them sends ACK to A along with their sender ID. If D is the first to send the ACK with its own ID as highest (as it is the first candidate in the forwarding list). So, if the C doesn't receive this ACK it sends its own ACK with own ID as the highest ID. At last B which has received the ACK sent by D, sends its own ACK with D as highest ACK. Thus C doesn't forwards the packet because it knows through B's ACK that The highest known ACK.

ExOR achieves higher throughput than the traditional routing but it has following drawbacks.
1.ExOR doesn't respond to the no updated measurements. It only considers the information available at the time of transmission. So, the incorrect measurements may degrade its performance and also may cause packet duplication.
2. It always seeks the coordination among all the nodes which causes overhead in case of large network. It doesn't reuse the information.

2.3Optimal Forwarder List Selection in Opportunistic Routing[4]

In this paper author proposes MTS algorithm for selecting forwarding list which minimizes the expected transmission rate under the ideal ACK condition. The assumption made here is that the low priority nodes can always here the broadcast of the high priority node thus there will be no duplicate transmission of packets. Under this assumption the author proposes the Minimum Transmission Scheme algorithm, which computes the optimal forwarding list. While using this algorithm in ExOR[2] instead of the ETX[3], the MTS based ExOR gives fewer transmissions than that of the ETX based ExOR. Thus the throughput of the MTS based ExOR is better than that of the ETX based ExOR. However in certain cases when the perfect ACK condition is not satisfied, the ETX based ExOR performs well than the MTS based ExOR.

2.4 Simple, Practical, and Effective Opportunistic Routing for Short-Haul Multi-Hop Wireless Networks[6]

Here author proposes the effective opportunistic routing scheme for short haul multi-hop wireless networks . This modified Opportunistic routing algorithm implements the scheme of sending the ACK after receiving packet. In this algorithm the only the destination can opportunistically receive the packet by overhearing the transmission of the nodes in the traditional networks. After the destination node receives the packet from the priori node it sends the ACK to all the other nodes in the path. The node will only retransmit the packet in case it did not receive the packet from either destination or next node in the path. Hence, the destination node can easily discard any duplicate packets. Thus this algorithm reduces the packet duplication rate. Also it increases the throughput than that of other opportunistic algorithms. It is simple and can be integrated with the other Opportunistic algorithm.

2.5 Spectrum Aware Opportunistic Routing in Cognitive Radio Networks[7]

Shih-Chun Lin and Kwang-Cheng Chen proposes the SAOR i.e. Spectrum Aware Opportunistic Routing for Cognitive Radio Network (CRN). The algorithm proposed by the authors uses the optimal link transmission (OLT) as a cost metric for prioritizing the nodes in the forwarded list. The OLT metric is considered in the delay aspect. Two more metrics namely optimal path metric and node metrics further elaborates the number of hops in the path and the delay status within each path respectively to the destination.

Due these metrics SAOR gives QoS guarantees like better throughput and improved end to end delay performances than the traditional routing algorithms for CN.

2.6 Energy-Efficient Opportunistic Routing in Wireless Sensor Networks[8]

This proposes the scheme to choose the forwarding list using the cost metric of minimum energy depletion while broadcasting in the wireless sensor network. Energy Efficient Opportunistic Routing (EEOR) calculates the expected cost for each node to forward the data and then selects the forwarding list. The basis of selecting forwarding list is that the expected cost of the node to be added must be less than the prefix forwarding list so that the total expected cost of the new forwarding list will be minimum. The expected cost updating of each node is done by the algorithm similar to the Bellman Ford algorithm.

EEOR consumes less time than that of ExOR for both transmission and receiving data. Due to the cost metrics considered in EEOR, the average size of the forwarding list of the EEOR is much less than that of the ExOR[2]. In case of the total energy consumption, EEOR performs better than EXOR[2]. Comparing both the protocols for the packet loss rate and end to end delay EEOR performs better than ExOR[2].

2.7 A theoretical model for opportunistic routing in ad hoc networks[9]

The author of this paper proposes the general framework to model opportunistic routing. It considers delivery ratios and the priority order among the nodes to select the next hop for the packet forwarding. It focuses on giving a closed form expression for average transmission number. This model helps to analyze the performance parameters such as packet dropping rate, packet transmission number, end to end packet delay etc.

2.8 A Trusted Opportunistic Routing Algorithm for Vanet[10]

The paper describes the trust mechanism for the security deficiency in the opportunistic routing algorithm. It describes the trade-off between the cost metric and security factor. The author proposes the algorithm which calculates the degree of trust and updates the direct trust degree. The degree of trust is based on the direct observation of the neighbouring nodes while indirect trust degree is based on the recommendation. By using these factors the author has implemented the Trust Opportunity Forwarding Mechanism using cost effective forwarding list and has prioritize each node in the list by its cost distance from destination.

The TMCOR algorithm performs well in all three metrics viz. throughput, end to end packet delay and security gains. TMCOR prohibits the malicious node to participate in the network by judging them in terms of trust degree. Thus, reducing End to End packet delay and increasing security gains.

2.9 A Novel Socially-Aware Opportunistic Routing Algorithm in Mobile Social Networks[11]

The author proposes the use of OR for the MANETs using the cost metrics such as social relations and profiles of the nodes. The proposed distributed protocol is Social Relation Opportunistic Routing (SROR) to compute best forwarding node in routing. The protocol mainly considers the social relations, mobility patterns and social profiles for Mobile Adhoc Networks (MANETs). For selection of the forwarding node in the routing SROR following three matching parameters are taken into account viz. social profile matching, social connectivity matching and social interaction. Hence when the node wants to send the packet, due to the algorithm there is high possibility that the best candidates sharing similar interest tend to meet again to forward the data. SROR gives high packet delivery rate and routing efficiency compared to other protocols for MANETs.

2.9 Opportunistic Routing Algorithm for Relay Node Selection in Wireless Sensor Networks[12]

This paper[12] mainly concerns about the energy savings concept in the WSNs. It describes the algorithm which focuses on minimizing the energy consumption of the network. The author proposes Energy Saving via Opportunistic Routing (ENS-OR). The algorithm implements the concept of energy efficient node (EEN) which happens to be a virtual relay node obtained by relay function on several real nodes based on their residual energy. The forwarder list selection and prioritizing the nodes in the that list is carried out by the ENS-OR algorithm calculates the optimal hop distance to calculate the next hop node to forward the data. The nodes in the forwarding list prioritize themselves by their residual energy and their distance from EEN.

ENS-OR obtains better network energy usage. Also it increases the network lifetime by achieving higher residual energy of the nodes in the network. The packet delivery rate of ENS-OR is greater than that of GeRaF[1].

Table 1. Comparative Study of OR Protocols

Protocol/ Metrics	Forwarding List Selection	Key Metrics for Prioritization Of nodes	Candidates Coordination in Forwarding List	Packet Duplication	End-to-End Delay Constraint	Energy Efficiency	Protocol Designed For which network?
GeRaF[1]	Hop by Hop	Geo distance	RTS-CTS	√	--	--	Ad-hoc Sensor Network.
ExOR[2]	End to End	ETX	ACK	√	--	--	Wireless Sensor Network
MTS[4]	End to End	ENT	ACK	--	--	--	Wireless Sensor Network
OR for short –haul Path[6]	Hop by Hop	Distance from destination.	ACK	--	√	--	Short haul Multi hop WSN
SAOR[7]	Hop by Hop	OLT	Spectrum sensing	--	√	--	Cognitive Radio Network
EEOR[8]	End to End	Expected Cost	--	--	√	√	Wireless Sensor Network
Theoretical Model for OR[9]	End to End	Packet Delivery ratio	--	--	--	--	Adhoc Sensor Network
TMCOR[10]	End to End	Trust degree	--	--	√	--	VANET
SROR[11]	End to End	SIM,SCM,SPM	ACK	--	--	--	MANET
ENSOR[12]	End to End	Residual Energy	Data Based	--	--	√	Wireless Sensor Network

CONCLUSION AND FUTURE DIRECTIONS

Opportunistic routing in WSN has attracted many researchers these days. Since OR utilizes the broadcasting nature of wireless networks it has been proven to be more efficient than the traditional routing approach foe WSN. The WSNs have many issues such as lack of a predetermined infrastructure of networks, limited battery power of sensor nodes, disastrous environmental conditions to which sensors are vulnerable etc. Resource allocation becomes the critical issue when it comes to sensor networks, since it has limited battery power. OR overcomes many of these issues regarding WSNs. It gives better utilization than traditional approach. The existing protocols based on OR have mainly focused on the Energy saving, reducing data redundancy, increasing the utilization etc. ExOR[2] is a first to implement OR in WSN, it improves the efficiency of routing but it has the problem of packet duplication which is further reduced in MTS[4]. OR also helps in protocol design for VANETs, MANETs and CRN which provides QoS guarantees and better throughputs.

In terms of future scope, OR has to improve in terms of energy saving techniques. Since, sensor nodes tends to deplete their energy fast, the energy saving becomes the prime issue for sensor networks. OR integrated with duty cycle assignment can prove efficient in terms of energy savings. Since all nodes in the networks need not be active all the time the nodes which are not supposed to take part in the transmission and receiving activities can be pushed to sleep mode. This mechanism can help to improve network lifetime.

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